BULLETIN OF
THE NEW YORK ACADEMY
OF MEDICINE

VOL. 46, No. 8 AUGUST 1970

NINETEENTH CENTURY WOUND MANAGEMENT OF THE PARTURIENT UTERUS AND COMPOUND FRACTURE: THE SEMMELWEIS-LISTER PRIORITY CONTROVERSY*

OWEN H. WANGENSTEEN

Regents Professor of Surgery
University of Minnesota Medical School
Minneapolis, Minn.

THE mid-19th century was a period of exciting ferment for medicine. The significant contributions of Vesalius[1] (1543) and Harvey[2] (1628) had much importance for the advance of anatomy, pathology, and physiology. However, their impact upon practical medicine and surgery was miniscule contrasted with the biological revolution that emerged after the discoveries of Pasteur,[3] which lit the way for Lister's (1867-1875) great impress upon surgery.[4] Koch's (1878-1882) development of cultural methods[5] gave birth to experimental microbiology, making assessment of bacterial virulence possible. When Koch demon-

*Presented at a meeting of the Section on Historical Medicine, December 10, 1969.

These studies were supported by Public Health Service Research Grant No. 1 RO1-LM-00050-03 of the History of Life Sciences Study Section, National Institutes of Health, Bethesda, Md., and by the Alice M. O'Brien Foundation and the Frederick and Margaret L. Weyerhaeuser Foundation, St. Paul, Minn.

strated his plate cultures at the International Medical Congress in London (1881), Pasteur is said to have rushed forward with the exclamation: "*C'est un grand progrès!*"[6] Ehrenberg's[7] monograph of 1838 had depicted and described bacteria but pragmatic clinicians took no note of them. Henle's[8] *Von den Miasmen und Kontagien* (1840) shifted the explanation of disease transmittal from "pestilential emanations" from bogs and swamps to microbial origin, though the designation "microbe" had to wait another 36 years.

Semmelweis'[9] astute inference, stemming from the death of his obstetrical colleague, Jakob Kolletschka (1847), was highly significant for understanding of the nature of puerperal fever, its transmittal, and its prevention. It is a unique example of penetrating insight without parallel in the history of medicine.

It is the purpose of this presentation to survey the practices of this period from 1847 to 1880 with special reference to the management of the wounds of compound fracture and of the parturient uterus. Examination of the contributions to practical wound management during this period will provide evidence that sheds light on the long-standing controversy between Semmelweis and Lister concerning priority of discovery.

Infection Still Challenges the Surgeon

Acceptance of antiseptics and asepsis did not eliminate the threat of infection in surgical procedures. Complete asepsis in operations is still to be achieved. During the lifetime of younger members of this audience, systemic chemotherapeutic and antibiotic agents virtually eliminated cellulitic infections. However, the less threatening staphylococcus of my training days is today the bête noire of hospitals and surgeons.

Over the centuries, before sulfanilamide and antibiotics became available, a number of promising young physicians lost their lives from fingerpricks sustained during work. Hunczkovsky (1798), Kolletschka (1847), Semmelweis (1865), and Curt Schimmelbusch (1895) were snuffed out in this manner. Dr. William Murray (1926), our professor of ophthalmology, pricked his finger during a myringotomy for otitis media. In desperation his arm was amputated but he died a few days later. One of my contemporaries, Lucy Wilder, a graduate student in anatomy, working with a culture of streptococcus, let a drop fall on

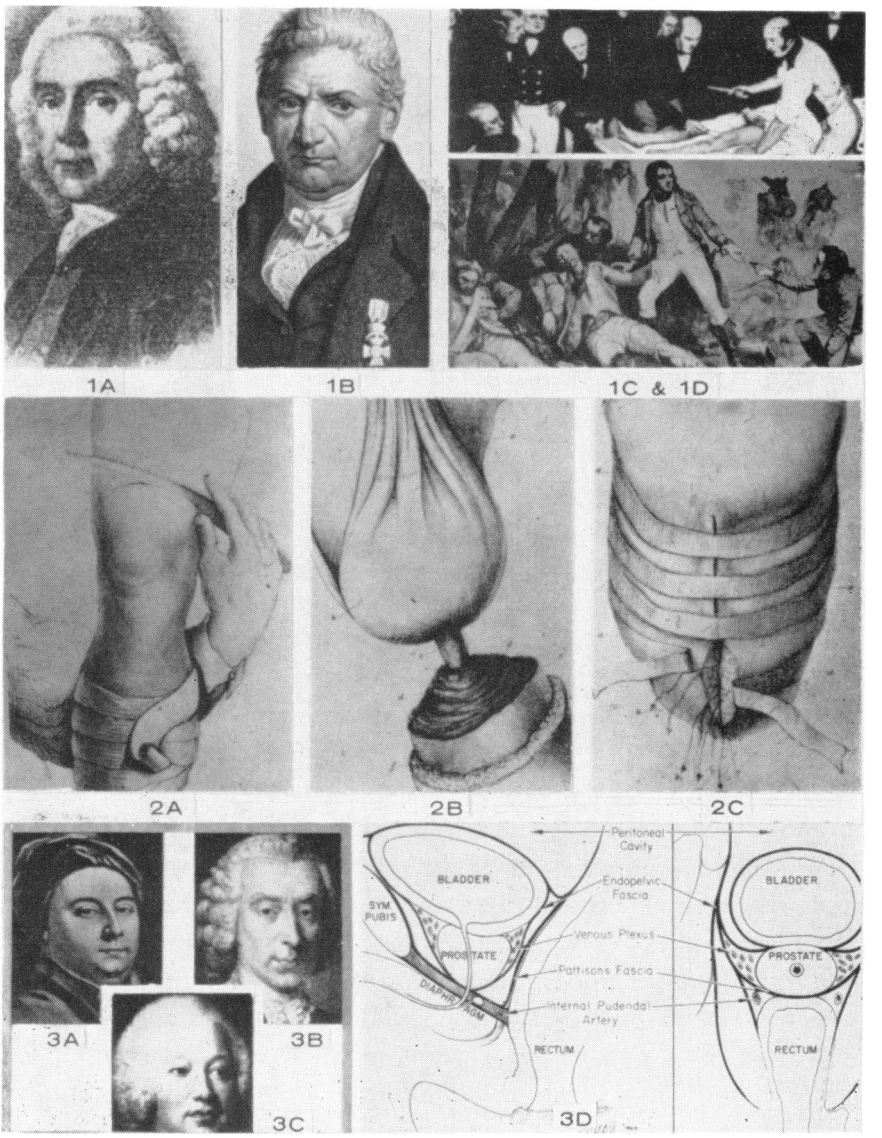
her forearm. She suffered a scratch at the site while injecting a rabbit. A few days later she died of septicemia. Even today the problem of infection follows the surgeon like his shadow and is a significant factor in most deaths after operation.

Antisepsis in many of its aspects extends back into antiquity. In the history of ideas, the microscope and techniques of growing and staining bacteria and using heat to destroy them contributed more to the surgeon's ability to cope with infection than all prior practices.

Elective Operations before Antisepsis

Theodoric, bishop of Cervia, and Henri de Mondeville, 13th-century surgeons, had striven for primary union of contaminated wounds.[10] Any compromise with this objective has been frowned upon by many historians of surgery. Yet in studies of the story of amputation it was noted that pre-Listerian surgeons such as Edward Alanson (1782), Vincenz von Kern (1809), Robert Liston (1837-1841), and A. Carl von Burow (1859-1873), all of whom left the wound open, achieved a rate of success unmatched until the arrival of aseptic surgery at the beginning of the 20th century.[11] Likewise Cl. Pouteau (1760) and William Cheselden (1723) and a few other skilled operators who performed lithotomy and left the perineal wound open to be washed by urine achieved records not surpassed until the aseptic era.[12] The explanation came only when Theodor Billroth (1865) showed that granulating wounds were far less susceptible than fresh wounds to invasive pyogenic organisms.[13]

Perusal of the literature of intestinal obstruction indicates that long before the days of antiseptic surgery, some surgeons had a record of accomplishment with external strangulated hernia and internal strangulation that deserves study. Astley Cooper, who was quite restrained in recommending operation for strangulated hernia, tried having the patient carried about the ward in the inverted posture over the shoulders of a strong ward attendant, hoping thereby for spontaneous reduction.[14] He recommended enemas of tobacco and suggested that surgeons who neglected this procedure did not appreciate its merit.[15] Yet a thorough search of Cooper's text indicates that his mortality of 42% for surgical relief of strangulated hernia in the first quarter of the 19th century was not grossly in excess of that of modern-day surgeons performing intestinal resection for that condition. Obviously



Figs. 1-3. *Eighteenth and nineteenth century amputation.* 1*a*. Monro, *b*. von Kern, *c*. Liston. *d*. Larrey. Fig. 2. Charles Bell's sketch of thigh amputation. Fig. 3. *Heroes of perineal lithotomy. a*. Cheselden. *b*. Pouteau. *c*. Louis. *d*. Anatomy of perineal lithotomy operation.

surgeons are not yet as alert as they should be to the threat of intestinal strangulation.

Some French surgeons more than two centuries ago in the heyday of the Royal Academy of Surgery had successes with internal strangulation which would surprise if not startle today's specialist. The only difference is that the French surgeon, after excising the dead bowel, left the adjacent viable open ends in the wound. Moreover, he occasionally was able to reestablish intestinal continuity by mobilizing and approximating the two stomas in the wound.[16] All this, mind you, before the days of anesthesia and antisepsis!

Intestinal resection obviously is a far more delicate operation than excision of an ovarian cyst. Yet ovariotomy (1809) had to await the pioneering courage of Ephraim McDowell of Danville, Ky.[17] His innovation came 75 years after intrepid French surgeons had dealt successfully with internal intestinal strangulations. The reasons for this long hiatus are not easy to find, but aspiration of ovarian cysts frequently provided temporary relief and could be repeated. Puncture through the rectum was done occasionally in the hope that the cyst would be permanently drained, a rather dangerous expedient, as subsequent events demonstrated.

Pre-Listerian Antiseptic Wound Practices

The long history of surgery is replete with accounts of the use of various agents now known to have antiseptic qualities. The wise men of the East brought gold, frankincense, and myrrh to the Christ child,[18] token gifts of great worth in that day. Myrrh and spirits of wine or alcohol and vinegar were favored in wound management by many surgeons. No surgeon, however, followed a course in which trials were made with consecutive use of a single medium now known to be antiseptic.

Turpentine stands out prominently as one of the most effective agents and one which early enjoyed wide use. John Woodall spoke of it often as good wound therapy in his *Surgeons Mate* (1655).[19] Matthaeus G. Purmann (1699) used turpentine with other ingredients in the management of compound fractures,[20] as did Johann von Muralt (1691).[21]

Other agents which have proved on assessment to have demonstrable antibacterial activity are alcohol, ammonium chloride in com-

bination with alcohol, vinegar or turpentine, ferric chloride, balsam of Peru, creosote, and zinc chloride. The story is too long to tell here but a number of surgeons, especially in the mid-19th century, documented series of cases in which such antiseptic agents were used with surprising and gratifying success in wound management. Lemaire[22] and Déclat[23] in Paris had anticipated Lister in the use of phenol, but unfortunately recommended it for many types of wounds, making critical assessment difficult. What the agents actually did was not understood until the germ theory of disease and the pathogenicity of bacteria became generally known.

Hippocrates' management of fractures has a modern ring. For compound fractures he advocated keeping the wound moist, and he placed a goatskin beneath the extremity in order to carry fluid away from the wound. He also used pitch cerate (turpentine) and wine dressings,[24] practices, says Malgaigne, that were continued by Celsus, Galen, and Avicenna. Malgaigne[25] relates that Ambroise Paré was a keen advocate of water irrigation for many types of wounds, including compound fracture,* an attitude shared by two later celebrated French military surgeons, Pierre-François Percy and Dominique-Jean Larrey of Napoleon's army.[28]

Henry Yates Carter (1792-1795), the Englishman, employed dressings soaked in a solution of vinegar and 3% ammonium chloride (sal ammoniac) for severe wounds and compound fractures. Occasionally he added 6% turpentine. Of 8 patients with severe wounds or compound fractures, in which the wounds were left open and treated in this manner, only one died, from shock, attending an accident which had severed the upper thigh and scrotum.[29, 30]

A unique effort was made by Jules Guyot (1835) to assess the effect of warm air upon wounds. For this purpose he built a square box into which he admitted air at temperatures of 30 to 40° and as high as 70° C. Preliminary experiments with the method were made on wounded rabbits. Jean-Edouard Laborie, an associate who participated in the experiments, reported 64 survival trials on 30 rabbits. Guyot concluded that the hot air had a beneficial influence on the wounds. Professor François Magendie, who had followed the study,

*Malgaigne admitted difficulty in defining the word "irrigation."[25] Perusal of Malgaigne's *Paré* would suggest that Paré more often used water dressings than irrigation.[26] The Pravaz syringe first became available in 1851. Three centuries after Paré, Billings related that when inducted as a surgeon in the Union Army (1861) he brought along a hypodermic syringe. It was in constant use, for no other surgeon had one.[27]

asked Professor Gilbert Breschet to try the method at the Hôtel Dieu. Observations were begun late in 1833 upon four patients with chronic ulcers. The first was submitted to a 36-hour trial with warmed air to the leg wound at an old fracture site; the oppressive heat, the patient insisted, damaged his lungs. The lesions of the three other patients apparently were all improved by the treatment. Laborie (1838) reported Guyot's observations in some detail "in the interest of science," believing the method had real merit.[31, 32]

During this same period, irrigations of cold water as devised by Bérard were being used enthusiastically in several Paris hospitals for compound fractures and other surgical wounds.[33, 34]

Macartney of Dublin (1836) recommended evaporation of water over a flame as an anti-inflammatory device in the management of all wounds, including compound fractures and battle injuries, noting that the vapor directed through a tube to the wound thwarted suppuration.[35] Vincent Nivet (1838) reported continuous water irrigation of the wound in compound fractures. Of nine patients treated in this manner, two died, a mortality of 22.2%.[36]

One of the most celebrated proponents of water dressings was Robert Liston. He "rode his hobby of water-dressing in the treatment of wounds rather hard," reminisced Erichsen in a fine account of Liston's successful open-wound therapy of the stump after amputation. "It was," says Erichsen, "the perfection of lightness compared with a poultice; the perfection of cleanliness contrasted with ointments. . . ."[37]

John Crowther (1802) wrote of the prevention of gangrene in compound fracture by a method, he said, that had been practiced with the greatest success by his ancestors near Halifax since time immemorial, being handed down from father to son. In his report Crowther related observation of 98 fractures from April 28, 1789, to October 5, 1800, of which 28 were compound; in none was there any evidence of gangrene. The same success, Crowther states, attended the practice of his two brothers William and Robert over many years.

It was the custom of the Crowthers to place "a large quantity of black basilicon ointment, made with tar instead of pitch, to be liquefied in an iron earthern pot, and made hot, then put into it with all dispatch a large pledget of tow, sufficient if possible to cover the whole wound, so as totally to exclude all external air." If one pledget was not

sufficient to cover all the lacerated parts, another was applied. The tow was dipped into the hot ointment, then placed directly over the wound. John Crowther next put on a roller-bandage dressing moistened with vinegar. For later dressings smaller amounts of hot basilicon were used. When purulent discharge occurred during convalescence the dressing was applied cold. Such moist bandages were continued until the inflammation abated.[38]

Baron Larrey (1824) implanted styrax into the wounds of compound fractures. Styrax is an ingredient of compound tincture of benzoin, which is an effective antibacterial agent. Larrey applied linen coated with styrax, then compresses soaked in wine or in camphorated vinegar as a dressing over the wound, and immobilized the extremity in a splint. A many-tailed Scultetus bandage was next crossed many times in an oblique direction over the fracture area. This dressing was changed only once or twice during the entire period of treatment.

Larrey relates, "a dozen subjects of the Guard were treated in this manner in our hospital from 1821 to 1824 uniformly and successfully." He cites two instances of his cavalrymen who fell from their horses, suffering severe compound fractures of the leg. With extension and a liberal dressing of styrax and compresses of camphorated vinegar, amputation was avoided and the fractures mended.[39]

When Larrey (1766-1842) wrote this (1824), his illustrious war years were behind him. In earlier days he had been a strong protagonist of early amputation for fracture by gunshot and had severed as many as 200 limbs in a 24-hour period, an occurrence which provoked the Scottish military surgeon H. Home Blackadder (1818) to accuse him of "operative mania."[40] Great as was Larrey's fame as a military surgeon, he obviously did not have sufficient influence later to win Parisian civilian surgeons over to his conservative therapy. Why his suggestion or a variant thereof was not tested in some of the large Paris hospitals is a mystery. Moreover, in recounting his management of battle wounds (1830), Larrey made no allusion to his important paper of 1824.[41]

In his monograph on subcutaneous surgery, Adams (1857) cites the unusual record of success of the late Mr. Edward Bennion, of Oswestry in Shropshire, who treated compound fractures regularly with compound tincture of benzoin.* After reduction of the fracture, Bennion

*Sampson Gamgee (*On the Treatment of Wounds and Fractures: Clinical Lectures*, 2d ed., London, Churchill, 1883, p. 125) mentions Adams' reference to Bennion but incorrectly dates Adams' publication as 1867 instead of 1857.

soaked a large piece of lint in compound tincture of benzoin and encased the bandaged extremity in a splint, which remained untouched for a month if there were no symptoms. Adams added that Bennion's unusual success* with compound fractures was well known in that area.[42]

Bryant (1876), using a compound tincture of benzoin, treated 14 consecutive cases of compound fracture at Guy's Hospital without a death.[43] In 1861 Bryant had noted that mortality from compound fracture in the prior 20 years at the same hospital was 38.3%; for those treated conservatively it was 27.1%.[44]

A quest for information on the management of compound fractures in published monographs in the first three quarters of the 19th century proved very disappointing. This challenging facet of wound management seems to have been avoided studiously. The texts of Alexis Boyer (1805), Pierre-Joseph Desault (1817), Astley Cooper (1832), Lonsdale (1838), Guillaume Dupuytren (1847), and J. F. Malgaigne (1859) are virtually bare of helpful suggestions concerning compound fractures. Great surgical historian that he was, Malgaigne overlooked the significant contributions of Crowther (1802) and Larrey (1824).

A monograph with the promising title, *Mémoire sur cent fractures compliquées guéries*, by Jolieu (1843) offers little useful information. Several of the fractures described were compound. The author occasionally alludes to washing the wound. However, he usually avoids saying what the wash was. In one instance (p. 52) it was tincture of myrrh which, if it contained as much alcohol as the tincture currently available, would certainly have been a good antiseptic. In one case that went on to amputation because of gangrene, the amputation wound was dressed with *baume de Arceus*, of which the active agent is turpentine.[45]

Paré had barely escaped amputation for a compound fracture of the leg,[46] as did Pott two centuries later (1755).[47] Larrey's report of 1824 documents the beginning of a reaction against primary amputation for compound fracture in civilian practice,† yet amputation continued to be the order of the day in the Crimean War (1854-1856), our

*Charles Talbot of the Wellcome Institute of the History of Medicine turned up this item: "In the *Oswestry Advertiser* for 8 April, 1869, the following notice appears: 'In another column we record the death of Dr. E. D. Bennion. . . . He was perhaps best known as the son of the celebrated Dr. Edward Bennion whose fame for surgical skill extended over this and many neighboring counties.'"

†In a Paris thesis of the Listerian era, Biencourt (1873) said that, "Larrey and [Auguste] Bérard had changed the treatment of compound fracture completely."[48] If the practices of Crowther (1802), Larrey (1824), and Bennion (1857) had been adopted by the profession, Biencourt's statement could have been significant.

own Civil War (1861-1865), and the Franco-Prussian War (1870-1871). In the Russo-Turkish War of 1876-1877, in the hands of a young Russian military surgeon, Carl Reyher, extensive debridement and antiseptic wound management succeeded in replacing primary amputation.*[49, 50]

Anesthesia was a great boon to both patients and surgeons in the reduction of fractures and dislocations. Caldwell of Louisville (1838) reported successful reduction of a compound fracture of the thigh by bleeding 24 to 26 ounces, until the patient became limp. When traction was applied no muscular resistance was encountered. Caldwell placed a firm roller bandage dressing over the fracture site.[52]

Lister and Compound Fracture

A force necessary to drive a splintered bone through the muscular and cutaneous integuments obviously must be a great force, resulting almost invariably in heavy contamination of the wound. The risk attending incised wounds in the preantiseptic era was measured almost solely by the surgeon's standard of cleanliness. The mortality of simple fractures was minimal, that of compound fractures was always large. It was to this type of wound that Lister applied his carbolic-acid dressing. In his first series of 11 cases there were two compound fractures of the femur, one of which ended fatally.† The others were mainly compound fractures of the leg, undoubtedly the most frequent variety. One of these resulted in amputation; the ultimate fate of the patient was not stated.[6] Also, in 1867, in a Paris thesis, de Ségogne wrote of the application of alcohol to wounds. He mentions six patients with compound fractures treated with alcohol dressings without mortality, the first in 1864, the others apparently in 1867. In addition he tells of one of La Peyronie's patients (prior to 1747) treated successfully with local applications of coal tar and brandy. Lister's discernment of the origins of the hazard in open fracture is missing in de Ségogne's account.[56]

*Puschmann (1889) relates that "Schmucker (1738) saw a patient at the Hôtel Dieu in Paris who underwent bilateral thigh amputation for simple fracture" ![51]

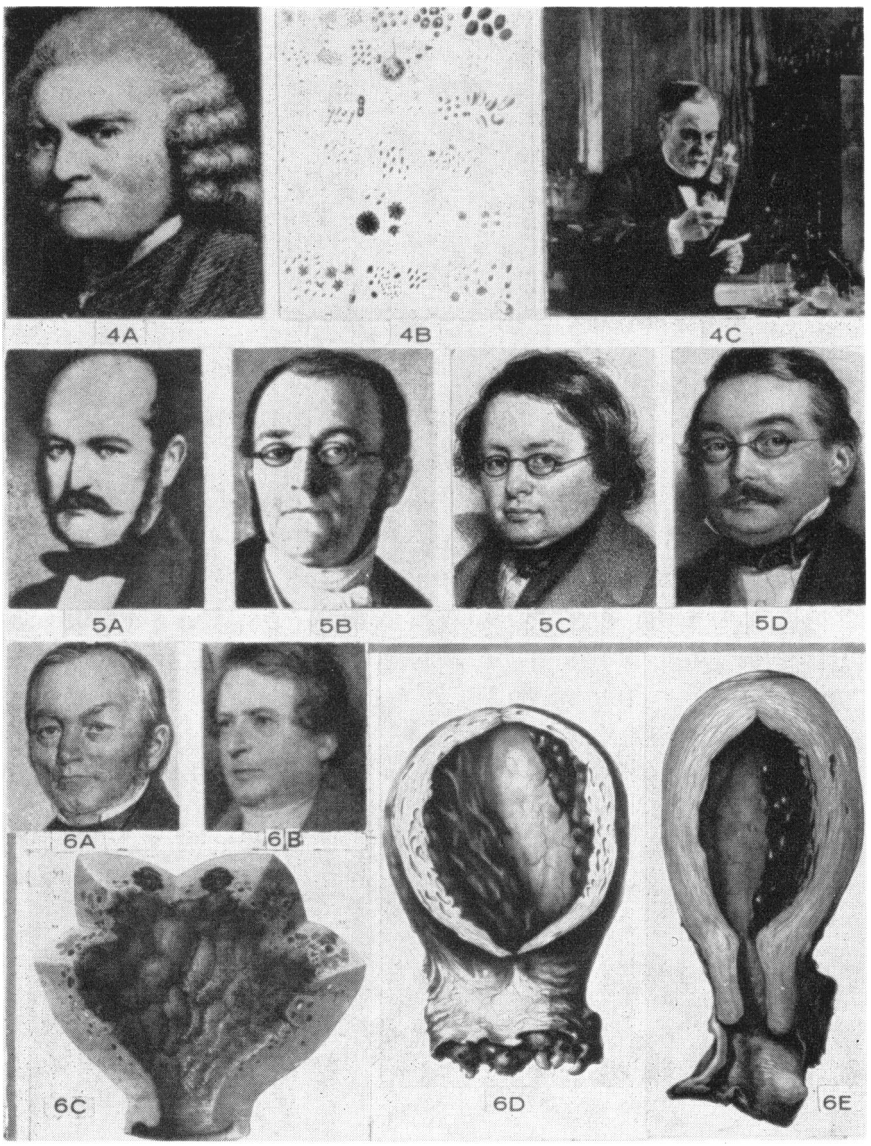
†Bøyer (1808),[53] Banner (1843)[54] and Huguier (1856)[55] alluded to the greater mortality of compound fractures of the lower extremity, contrasted with similar fractures in the arm or forearm; the reasons are not entirely clear, but soft-tissue injury is undoubtedly one factor. In the first edition (1826, p. ix) of his monograph on the *Application of Lunar Caustic*, Higginbottom asked if the eschar produced could thereby "reduce the case to the state of a simple fracture"?, a question repeated in the second edition of 1829. In the third edition (1865), Higginbottom stated (p. 5): "The eschar from the nitrate of silver excludes the atmospheric air from the wound and so reduces the dangerous circumstance of compound fracture to that of a simple fracture, the wound being healed by the first intention."

Statistics

Florence Nightingale (1859) lamented that statistical materials were woefully incomplete.[57] The same could well be said of the results of operations. Accomplishment was so poor for most operations that surgeons were reluctant to publish their over-all experience. One can read through large tomes on fracture and find bare mention of the results in compound fractures. Great surgeons such as Liston, William Fergusson, and John Erichsen wrote monographs and discussed problems philosophically without providing an assessment of their own experiences.* Said Sir James Paget in 1862, "Every surgeon has lost a large proportion of his patients after those operations [hernia tracheotomy, and trephining]: but the operations themselves are very rarely the cause of death; the worst that can be said of them is that they do not always save lives. For myself, I have, as yet, scarcely lost a case in true consequence of either of these operations; yet nearly half of those cases that I have operated on for hernia have died, and more than half after tracheotomy, and nearly all after trephining. But these were deaths after operations; not because of them."[58]

Said Volkmann (1877), "It is not everyone who has the courage of my friend, Professor von Nussbaum, who . . . has not hesitated to put in print that of sixty-four thigh amputations performed in military and civil practice combined, during the sixteen years immediately preceding the introduction of antiseptics, he had only saved seven cases (89% mortality). After Nussbaum's admission, it is very easy for me to acknowledge that my own results were very little better. But now, since introduction of the antiseptic method of treating wounds, I get more successful cases in a single year than during the whole of my surgical career."[59] Acceptance by a few distinguished Continental surgeons—Danish, German, and Swiss—of the antiseptic management of compound fractures was the beginning of the end of stubborn resistance to Lister's practices though opposition lingered for almost a decade in high places in England and the United States.

*Alexander Miller, in his "Inquiry into the average mortality in Lithotomy cases" (1831, pp. 8-11), complained that reliable hospital statistics were rarely available. Marcet (1819, p. 24) wrote: "it is scarcely credible that in the largest hospitals of London, St. Bartholomew's, St. Thomas', Guy's and the London Hospital, no regular or at least no ostensible records of the cases of lithotomy . . . should be preserved." (*An Essay on the Chemical History and Medical Treatment of Calculous Disorders.*)



Figs. 4-6. *Puerperal fever.* 4*a*. Pringle, author of "antiseptic." *b*. Bacteria (Ehrenberg, 1838). *c*. Pasteur, who labeled streptococcus as cause, 1879. 5*a*. Semmelweis. *b*. Rokitansky. *c*. Skoda. *d*. von Hebra. 6*a*. Klein. *b*. Rosas. *c*. Gangrenous uterus, 4th day. *d*. Uterine wound after delivery. *e*. Normal uterine involution, 3d day.

Puerperal Fever

It is strange that large works on surgery often fail to mention puerperal fever, yet the post-partum uterus provides a big fresh raw wound. On basis of measurements provided by Lea (1910), the area can be said to be approximately 900 sq. cm.[60] A more recent evaluation by Kehrer (1952) is in general agreement: the placental attachment, the segment of greatest denudation, constitutes about one third the area.[61] This large wound is obviously a fertile source for bacterial implantation. The analogy, therefore, between wounds of the parturient canal and surface wounds is an acceptable parallelism and gives Semmelweis a significant place in the history of wound management.

Among the first to recognize the similarity between surgical wound infections and puerperal fever were Pouteau (1760) and Kirkland (1774).*[62] "Attentive examination" of the cadavers of women dead of puerperal fever revealed to Pouteau "ravages of an erysipelatous-like inflammation."[63] It remained, however, for James Simpson (1851-1856) to give this thesis articulate expression, an observation that apparently escaped Lister.[64, 65]

It is to be recalled that in mid-May, 1847, Semmelweis introduced into the obstetrical services at the Allgemeines Krankenhaus at the University of Vienna a technique that made an amazing impact upon the incidence and mortality of puerperal fever. As Semmelweis relates (1861), he instituted a plan of hand washing with warm soap and water, followed by thorough washing in chlorine solution until the hands became slippery. "Hands so treated," said Semmelweis, "are completely disinfected." He said further: "The carrier of decomposing materials is not alone the examining finger, but all situations and materials which are unclean and which come in contact with the patient's parturient canal." These agents too, Semmelweis insisted, must be similarly disinfected before use (p. 103). To this category Semmelweis assigned "instruments, bed cloths, sponges and washbasins, etc., etc." (p. 269).

The death of his colleague, Kolletschka, from a fingerprick sustained during a dissection performed on a patient dying of puerperal fever prompted Semmelweis to institute the chlorine hand-washing technique. Semmelweis' assessment included a study of the mortality

*Thomas Nunneley in a *Treatise on Erysipelas* (1841) emphasized the similarity of puerperal fever and erysipelas.

statistics for parturient women at the hospital. He found that between 1784 and 1823 the annual death rate was less than 1%, but that between 1822 and 1824, when medical students began to participate regularly in post-mortem dissections while on obstetric call, there was a significant rise in maternal mortality.

In the beginning Semmelweis stressed the importance of the surgeon's hands and fingers transporting putrescent materials from the dissection of fresh cadavers, many of which represented deaths from puerperal fever. However, having observed that puerperal fever was transmitted also from the lochia of a woman dying of cancer of the uterus and subsequently from a patient with purulent infection of the knee, Semmelweis in his publication of 1861 (p. 59) included decomposing animal-organic matter of whatever source (from utensils, instruments, linen), "living organisms" as sources of infection. Semmelweis rightly concluded that puerperal fever is not contagious save by contact with a source of infection or infected materials (pp. 103, 269). He also stated that such decomposed animal-organic material can be communicated by anatomists, surgeons, and patients on surgical stations (p. 106).

Semmelweis concludes his monograph (p. 537) by saying that in the not distant future the only instances of puerperal fever would occur through self-infection. Then he adds, "If I shall be denied the privilege of seeing with my own eyes the conquest of puerperal fever, the conviction, that sooner or later this thesis will find acceptance, will cheer my hour of death."[66]

One feature which distinguished the Semmelweis era (1847-1849) from the Listerian (1867-1878) was the change in status of the biological sciences. By the time of Lister, microscopy and cultural methods were beginning to be accepted by pathologists and clinicians, thus heralding the birth of the science of microbiology, to which the brilliant and consecutive labors of Pasteur (1862-1878), Koch (1878-1882), and others, lent great impetus.

When Semmelweis instituted chlorine hand washing as a routine procedure for the accoucheur, bacteria had been described by Ehrenberg (1838),[7] but for most clinicians his work had no meaning. Carl Rokitansky, in whose institute Semmelweis did his dissections, had at first abjured the microscope, as had John Hunter.*[67] Rokitansky's

*Rosas, who with Klein deprived Semmelweis of his appointment at the University of Vienna (1849), was a vigorous opponent of microscopy. His pupils could pursue microscopic studies in ophthalmology only behind locked doors.[68]

neglect of the microscope in his multivolume treatise on pathology (1842-1846) evoked severe censure from Virchow (1846). Had Rokitansky counseled Semmelweis to examine microscopically the lochia of parturient women, he probably would have observed the organisms which Ehrenberg depicted and which Pasteur later (1879) labeled as the cause of puerperal fever.[69] Yet Pasteur's announcement did not find ready acceptance amongst obstetricians in Paris.

Fleetwood Churchill (1849) collected the writings of several British students who wrote about puerperal fever before 1800.[70] Gordon (1795) recognized the relation of the attendant accoucheur to the origin of the disease but did not indicate how the contagion was conveyed, presumably on the accoucheur's raiment. He believed that if he could see the patient within the first 12 hours, there was an excellent chance of cure—the remedy was bleeding of 20 to 24 ounces and purgation![71]

Collins' brilliant work at the Dublin Rotunda Hospital* in reducing the incidence of puerperal fever by strict sanitary measures including fumigation of the obstetrical wards is especially noteworthy. Whitewashing all woodworks, including floors, walls, and ceilings with chloride of lime gave the hospital an air of cleanliness. Collins' low mortality record of maternal deaths, 0.54%, was the envy and goal of all obstetricians.[72] Collins, however, was unaware of how the contagion of puerperal fever was communicated. Since he was a 19th century obstetrician, his name was not included in Churchill's review, nor was that of Oliver Wendell Holmes (1843) who, like Gordon, recognized that the physician conveyed the infection. Holmes advised physicians to wash their hands in chloride of lime *after* visiting patients suffering from puerperal fever.[73]

In a very perceptive and painstaking effort Erna Lesky, professor of the history of medicine at the University of Vienna, has dissected the events leading up to Semmelweis' dismissal.[74] It was not simply a matter of difference between the pupil Semmelweis and his superior, Johann Klein, but more realistically a power struggle in the faculty between the old and the new. Johann L. Böer, Klein's preceptor and predecessor,

*Semmelweis had planned to work in the Rotunda obstetrical wards before his dismissal in Vienna (pp. xxvii and xxx).[66]

was deposed in 1822 from his position as chief of the University Obstetrical Service, to be replaced by Klein.*[75]

The crafty maneuverer, Anton E. von Rosas, professor of ophthalmology, and Klein represented the old; Rokitansky, who was dean of the faculty, J. Skoda, F. von Hebra, Carl Haller, Ernst Brücke, Dlauhy, Johann von Dumreicher, and others, the new. The year 1848 marked the coming of a revolution in Europe that extended from the Baltic to the Mediterranean, and the decision of the Ministry of Education in Vienna may have represented in part an entrenchment against innovation. In any case, in retrospect, the fact that Klein and Rosas, two undistinguished members of a great faculty, could offset the judgment and recommendations of Dean Rokitansky and a brilliant staff, defies understanding.

The Semmelweis-Lister Controversy: Priority of Discovery

Since publication of a brief paper on Preludes to Lister in 1965,† the centennial of Lister's first trials with phenol and compound fractures, I have continued to study the question of who was the inventor of antiseptic surgery. Pringle (1753) showed that putrefaction in small dead animals could be prevented by immersing the bodies in dilutions of mineral acids.[76] Semmelweis anticipated and *prevented* wound sepsis by the use of an antiseptic, chlorinated lime. His perceptive intuition is the more remarkable in that the germ theory of disease was still latent and had not been subjected to the test of trial and controversy. His cleansing and antiseptic treatment of the accoucheur's hands protected the parturient against infection and became the first overt systematic application of the antiseptic principle. Semmelweis' practice was antisepsis in the true sense.‡ Joseph Lister's was an attempt to control existing infection by the application of an antiseptic, carbolic acid, to the wound, a technique which has since been abandoned in favor of wound excision and revision.

*Boer employed the phantom rather than the cadaver to teach students the technique of delivery. He was conservative in his methods and followed the expectant plan of noninterference during descent of the unborn infant upon the mother's pelvic floor as opposed to the French school that favored instrumental delivery.[68] Boer has often been referred to as the founder of modern obstetrics. Semmelweis apparently had no direct contact with Boer, but probably was influenced by his teachings.

†Wangensteen, O. H.: Preludes to Lister and the interdependence of the sciences. *Surgery 58*:931-34, 1965.

‡Dr. Glenn E. Bartsch, associate professor of biometry, University of Minnesota, subjected the maternal mortality rates of the first Vienna Obstetrical Clinic (1784 to 1848) to statistical analysis. In the year 1819 and in the entire period from 1823 to 1846 the maternal mortality was excessively high, exceeding 3.66%. In the years 1847 and 1848, the maternal mortality was strikingly lower, 2.98 and 1.28% respectively. The test for Extreme Values indicates that these data have a high level of statistical significance ($p > .01$).

It has been said that Lister discovered antisepsis. Those who disaffirm this often suggest that he introduced a new principle; Lister himself called it the antiseptic principle. Of course, he did neither. Pringle (1750) coined the word "antiseptic."[77] Semmelweis (1847) recognized the mode of transmission of contagion and employed a solution of chlorinated lime to *prevent* puerperal fever, disinfecting all material likely to come in contact with the parturient's vaginal tract. Auguste Nélaton (1852-1864) had used alcohol in major elective surgery with considerable success.[11] What Lister did do was to introduce the scientific method in examining the effectiveness of a succession of antiseptic agents in wound management. Lister's test case was a good one, viz., compound fracture.

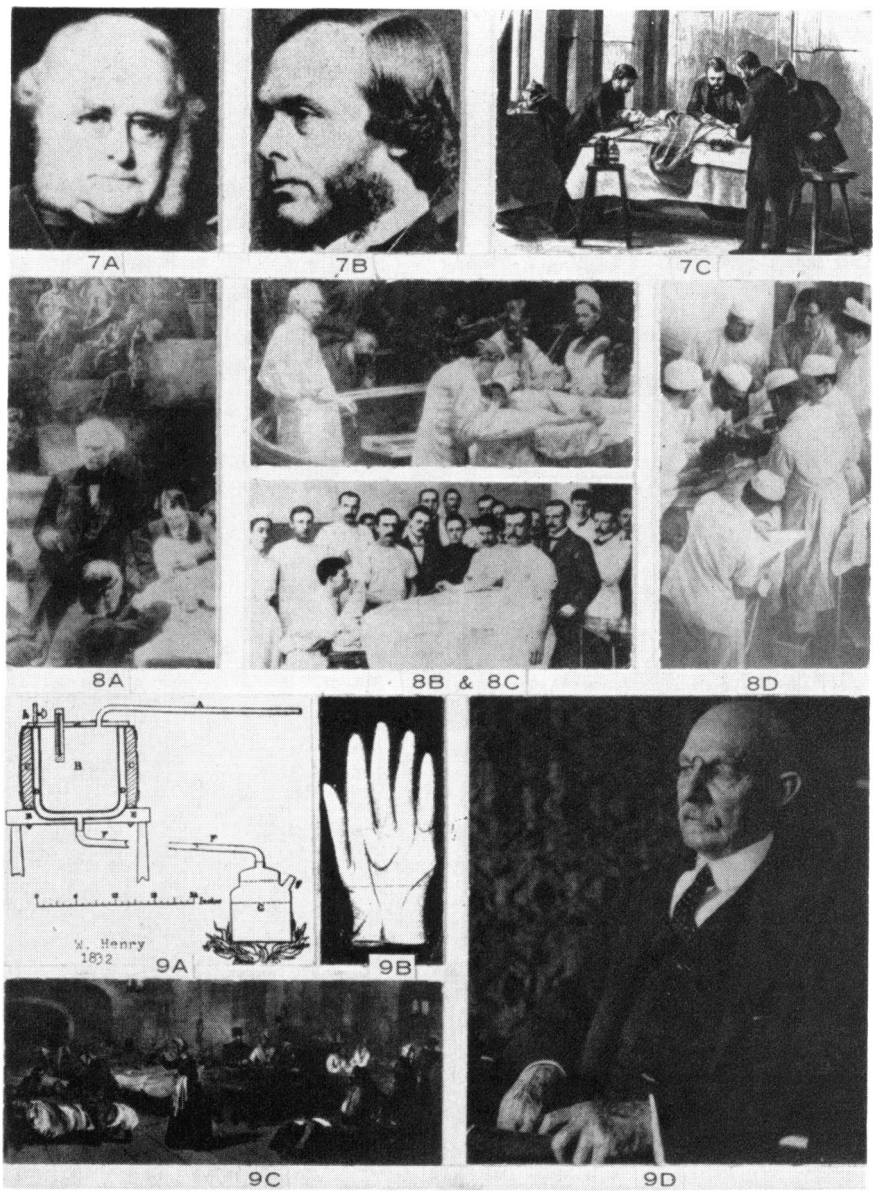
Who Is the Discoverer?

When the priority of discovery is debated, three items bear upon the issue: 1) Who first showed the way? 2) Continuance of the practice. 3) The influence of the discovery upon contemporary practice.

Semmelweis' insistence on disinfection of the accoucheur's hands and of all materials likely to come in contact with the large raw wound of the parturient uterus is a practice that is continued up to the present time. His shrewd assessment of the nature of contagion and puerperal fever has rarely been matched in medicine.

Lister's work had a more far-reaching significance for surgery. His first attack upon wound contamination was application of carbolic acid to the wound and efforts to minimize contamination from the air (carbolic-acid spray), accompanied by sterilization of the surgeon's hands and instruments with phenol.

Dakin's solution (Semmelweis' chlorine wash) found wide usage in World War I and the ensuing period until the arrival of sulfonamides. Lister's method of placing antiseptics in wounds has almost completely disappeared. Such chemical agents, while destroying bacteria, also damage tissues. Debridement is today the accepted remedy for compound fractures; it is complemented by forceful irrigation with saline solution (an old method) and administration of a broad-spectrum antibiotic. Long before Friedrich (1898)[78] demonstrated the efficacy of wide excision of an infected area when done within six hours, Reyher (1878) showed the value of extensive debridement of battle wounds. The surgery of World War I served to reemphasize this technique.[50]



Figs. 7-9. Surgery progresses. *7a.* Spencer Wells, 1864. *b.* Lister, who used phenol in open fractures, 1867. *c.* Operation in Lister's clinic, ca. 1870. *8a.* Gross. *b.* Agnew, 1889. *c.* Kelly, *d.* Halsted operating, 1904. *9a.* Henry, sterilization. *b.* Forster, rubber gloves, 1878. *c.* Florence Nightingale, Crimea. *d.* Halsted.

Recent studies have shown that topical application of antibiotics in wounds does lessen the hazard of wound infection, but whether it is superior to systemic administration of antibiotics is questionable. The most effective agent, however, is adequate wound debridement.*

The medical world of Semmelweis' day was not ready to accept contamination of the accoucheur's hands as the source of puerperal fever. In this sense, the genius of Semmelweis was his own nemesis: he was too impatient with criticism which he felt was unwarranted and was reluctant to publish.† Semmelweis had already demonstrated that when the lochia from women with puerperal fever was placed in the vagina of female rabbits directly following delivery, sepsis did not occur if chlorinated lime also was introduced into the rabbit's vagina.[79]

Mayer (1862) found "vibrios" in the vaginal canal of multiparous women who complained of burning and itching of the vulva.[80] In May 1865 Mayrhoefer was able to demonstrate the presence of microorganisms in the lochia of women with puerperal fever.[81] Späth‡ (1864), at first an opponent of Semmelweis, noted the low mortality amongst *Gassengeburten* ("alley births," patients who delivered before reaching the hospital) was influenced by the success of Semmelweis' program of preventing contact infection and capitulated to his practices.[82]

Announcement of Discovery versus Proof of Its Validity

Is it the discoverer's responsibility, beyond the announcement, to effectuate adoption of the principle he advocates? In the view of the public, this would appear to be the situation. I need allude only to Edward Jenner and smallpox vaccination and to Jonas S. Salk and Albert Sabin, famed for their work with vaccination for poliomyelitis. Nobel Prize committees, on the contrary, are more likely to trace the story to the person who made the telling observation which eventuated in the conquest. For their method of demonstrating how the poliomyelitis virus could be cultivated, John F. Enders and his colleagues, Frederick C. Robbins and Thomas H. Weller, were cited by the Nobel Prize

*After a long operation and following resection procedures in the alimentary canal, excision of the soft tissues in the wound edges, including skin and fat of the subcutaneous tissues, will probably eliminate more bacteria in a few seconds than can be achieved by any other means. A controlled trial would soon determine the validity of this suggestion.

†The *Aetiologie* (1861) provides good evidence of Semmelweis' lack of skill in writing.

‡The story of Vienna obstetrics and obstetricians from the founding of the University (1365) and the establishment of the first chair in obstetrics (1754) is well told by Isador Fischer in *Geschichte der Geburtshilfe in Wien* (1909).

Committee (1954) before the work of Salk and Sabin had shown conclusively the effectiveness of the vaccination program. For demonstration of the utility of angiographic techniques, the Nobel Committee awarded the prize in 1956 to D. W. Richards and André F. Cournand but also reached back to Dr. John Forssmann (1929), who had made the first heroic cardiac catheterizations upon himself and thus demonstrated the potential of the method.[83]

Empiricism almost invariably precedes the scientific approach, as witnessed by use of antiseptic agents by many surgeons over centuries to lessen the threat of suppuration in wounds. In the time of Semmelweis, the existence of bacteria was known but their relation to disease and to wound infections had not yet been clarified. Long after the germ theory of disease found almost universal acceptance, some surgeons were still asking: "How can bacteria possibly do any harm? We all live surrounded by them and they do not seem to hurt us. Why are they hazardous in wounds?"[84]

There is usually an anachronistic relation between empirical discovery and factual objective evaluation. A host of researchers from various disciplines today, including surgeons, are struggling in an empirical manner to resolve the problem of tissue rejection in transplantation. Perhaps someone doing empirical trials will stumble upon a fruitful method. The surer approach, however, is factual validation of the nature of rejection and the mode of preventing it.

It is a great thing to be able to press a button and in an instant produce light. What an intricacy of effort and sophistication goes into the conversion from darkness to light and of ignorance to understanding! Such is the story of aseptic surgery, the product of a number of contributions from many disciplines.

Lister's Avowed Ignorance of Semmelweis' Work

Godlee (1917) has written a very sensitive and penetrating biography of his uncle, Lord Lister, including a nice account of Semmelweis' work. He quotes from a 1906 letter of Lister to Dr. Weckerling: "When in 1865 I first applied the antiseptic principle to wounds, I had not heard the name of Semmelweis and knew nothing of his work."[85] This is indeed a strange statement from a person who had been a student of the problem of inflammation since the middle 1850's. As Erna Lesky (p. 41) has remarked, "Scarcely ever had a discovery attained such

quick publicity as did that of Semmelweis."*[74] Hebra,[86,87] Skoda,[88] and Haller[89]† all read papers announcing Semmelweis' important work (1847-1850) and Semmelweis himself appeared twice before the Vienna Medical Society to discuss his methods.[90]

The Englishman D. H. F. Routh, who had been a student in Vienna, returned to London and gave a paper on Semmelweis' doctrines before the Royal Medical and Chirurgical Society in November 1848. An abstract of his communication appeared the next month in the *Lancet*. The paper was published in the society's *Transactions* in 1849. Reviews of Routh's paper appeared in other English publications and in America and Scotland.[91]

Arneth (1851), a friend and colleague of Semmelweis in the Vienna Clinic, went to Paris,[92] Edinburgh,[93] and Ireland to announce the importance of Semmelweis' discovery. He later moved to Moscow, where he took a leading part in the discussions (1863) of Semmelweis' work at meetings of the St. Petersburg Medical Society.[75] The Irish surgeon E. W. Murphy published Semmelweis' findings in the Dublin *Quarterly Journal of Medical Sciences*.[94] In fact, in 1862 Semmelweis submitted a brief summary of his work, "On the Origin and Prevention of Puerperal Fever," which appeared in the *Medical Times and Gazette* (June 7, 1862, pp. 601-02), and was reprinted in *Braithwaite's Retrospect* in 1863 (vol. 46, pp. 150-53). In 1864 a review of Späth's report on the mortality of puerperal fever in Vienna appeared in the *British Medical Journal*, which alluded to the significant work of Semmelweis.[82] It would have taken very little effort for someone with a professed keen interest in inflammation and who, like Semmelweis, appreciated the identity of surgical and puerperal fever, to acquaint himself with the effective prophylaxis devised by Semmelweis for thwarting infections of any large wound of the parturient uterus.

Wieger of Strasbourg (1849) published his favorable experiences with the Semmelweis method. He concluded by saying, "Semmelweis acquainted an English obstetrician with his technique who said that on his side of the channel the technique was not new and that all his

*It is abundantly clear from Lesky's account (p. 215) that many members of the Vienna faculty appreciated the great significance of Semmelweis' discovery. Leopold Auenbrugger's discovery (1761) of percussion had gone unnoticed by Vienna's first medical faculty, an oversight which Skoda, Hebra, Rokitansky, and Haller felt strongly should not be repeated in the instance of Semmelweis. Whenever, before or since, have colleagues struggled so valiantly and sympathetically, even though ineffectually, to alert a profession to a great discovery?[68]

†In a presentation before the Pathology Section of the Vienna Medical Society, February 23, 1849, Haller,[89] adjunct director of the Vienna Allgemeines Krankenhaus, indicated that the mortality from puerperal fever on the First Obstetrical Service had been reduced more than 80% by Semmelweis' introduction of chlorine antiseptic methods.

colleagues changed their clothes when leaving the hospital!"[95]

In the French Academy of Medicine the Semmelweis thesis of the origins of puerperal fever was roundly debated in sessions from February 23 to July 6, 1858.[96] However, trial, not debate, is the proper manner in which to resolve a question of this kind.

When Klein, professor of obstetrics, died in 1856, Carl Rokitansky together with Dumreicher, professor of surgery, and Dlauhy, professor of public health, and Skoda, professor of medicine, urged the recall of Semmelweis for appointment to the chair of obstetrics in the University of Vienna; the recommendation of this distinguished committee was ignored. It is a tragic story reflecting intrigue and lack of vision. History does have a way of repeating itself.[74]

Lister and James Syme's eldest daughter, Agnes, were married in April 1856. A goodly portion of their honeymoon was spent abroad and they returned to Edinburgh in October. They had passed two weeks in Vienna, where Rokitansky, who had been a guest in Lister's home many years before, returned Lister's hospitality generously. The young Listers were entertained in Rokitansky's home and Rokitansky spent three hours and a quarter, Godlee relates, in showing Lister and other visitors his museum.[85] Lister, an accomplished microscopist, had begun his studies (1855) on the early stages of inflammation. Rokitansky also had taken to microscopy since his censure by Virchow (1846). Lister's visit to Vienna was made about the time that Rokitansky and others of the Vienna faculty were urging the appointment of Semmelweis as Klein's successor. Can it be that Lister in his two weeks in Vienna and in intimate conversations with Rokitansky did not hear the name of Semmelweis? The Medical Faculty undoubtedly was still buzzing over the controversy about Semmelweis' appointment. It would have been strange indeed for an ambitious young surgeon interested in inflammation not to have heard of Semmelweis and his work.*

It is proper that Semmelweis be recognized as the discoverer of the role of antiseptics in preventing wound infection. It is fitting to honor Lister as the leader whose careful study of the influence of antiseptics on compound fractures lent meaning to the provocative work of Pasteur for surgery. The coordinated contributions of a number of disciplines brought asepsis into being and greatly extended the realm of surgery.

*The *British Medical Journal* (August 26, 1865, p. 215) considered Semmelweis' death important enough to mention.

Transition to Asepsis

Practicing physicians long harbored patronizing attitudes toward paramedical scientists who dabbled in medical research. The physician-experimentalist Claude Bernard said to the chemist Pasteur at a meeting of the French Academy of Medicine that "when a doctor enters a room, he always looks as if he were going to say, 'I have just been saving a fellow man!'"[97] When the zoologist Fritz Schaudinn announced discovery of the *Treponema pallidum* from a chancre as the cause of syphilis (1905) at a meeting of the Berlin Medical Society (*Berl. Klin. Wochensch* 42:729-34, 1905), the presiding officer Ernst von Bergmann remarked, "The discussion is closed until our attention is called to the next announced cause of syphilis." A certain skepticism is a healthy quality, but the history of wound management is replete with doubting Thomases who, as members of commissions or adjudicating committees, obstructed and retarded the progress of surgery between the time of Semmelweis and Lister.

After his first publication in 1867, a series of important papers emanated from Lister's pen and clinic. Lister abandoned carbolic acid and the carbolic spray and explored a succession of other antiseptics. In 1907, 14 years after his retirement at Kings College Hospital, Lister prepared a powder-wound dressing of "the double cyanide of mercury and zinc" to which he added rosalane (Rosanilide) as a dye.[98] Rosanilide has recently been demonstrated to be a very effective antiseptic.

As early as October 1868, trials of carbolic acid in compound fractures were begun in Leipzig.[99] Just Lucas-Championnière interrupted his medical studies in Paris in 1868 to observe Lister in Glasgow. He returned to Paris full of enthusiasm, and by persistent effort gradually won support from French surgeons.* Influenced by commissions whose verdict was "not proved" (1864, 1866), French surgeons had earlier rejected Auguste Nélaton's alcohol soaks for elective surgery, as well as J. Lemaire's and G. Déclat's use of carbolic acid for wounds.[11] It was Lister's methodical consecutive labor that carried the day. However, 10 years were to elapse before his work gained enthusiastic endorsement from Volkmann of Halle, Germany (1877).[59] Gradually resistance lessened and aseptic surgery came with the work of Pasteur

*See unsigned obituary of "Just Lucas-Championnière" (*Brit. Med. J.* 2:1186, 1913).

Fig. 10. *Contributors to advance of surgery. a.* Nélaton, alcohol soaks in elective surgery (1852-1864). *b. Volkmann,* protagonist of Lister. *c.* Reyher, debridement in military surgery, 1878. *d.* Friedrich, proved value of debridement, 1898. Fig. 11. *Beginnings of asepsis. a.* Pasteur, 1878. *b.* Koch, cultured bacteria, 1878. *c.* Neuber, 1883, implemented asepsis in surgical practice. *d.* Bergman, demonstrated value of asepsis. Fig. 12. *Great innovations and innovators. a.* Tourniquet, Petit, 1718. *b.* Anesthesia, 1846. *c.* Semmelweis, demonstrated hazards of unclean hands in wounds, 1847. *d.* Lister, confirmed value of antiseptics for wounds, 1867.

(1863-1879), John Tyndall (1877), and Koch (1878). Their discoveries were put to clinical test by Neuber (1883),[100] von Bergmann (1891),[101] and Schimmelbusch (1892).[102] Mikulicz initiated the wearing of face masks (1894) to reduce droplet infection of the wound from the nose and mouth of the surgical team[103] and Halsted followed with rubber gloves* (1890-1897).[105] Thus the mystery of wound suppuration was finally unraveled and its threat to surgeons and their patients lessened. Erysipelas and parotitis, though no longer rampant in surgical wards, continued as an occasional postoperative complication until sulfanilamide and the antibiotics arrived to rid hospitals permanently of their hazards.

It is a long and thorny trail, from the microscopists Athanasius Kircher (1658) and Antonj van Leeuwenhoek (1696) to the contagionists Francisco Redi (1671) and Lazaro Spallanzani (1765), to the biologists Theodor Schwann (1836) and Matthias J. Schleiden (1838), and the histologist Jacob Henle (1840). The significant work of these biologists preceded the surgeon-actors' appearance in the drama but apparently were without meaning to the myopic physicians and surgeons of the mid-19th century. Thomas Trotter in 1806 wrote scornfully of the "relicts of the old animalcule" hypothesis of contagion.† Wound infection became intelligible only when Pasteur marshalled patrols of vibrios onto the scene and was followed by Koch with battalions of bacteria of demonstrated virulence.

A function of the educator is to recognize a man of promise before the world proclaims him. The discerning discoverer, Semmelweis, made a significant assessment on a few facts that were meaningful to him but he failed to persuade other workers. In this unbelieving world, the anachronistic observer with a message, born before his time, as this account reaffirms, encounters suggestions of sympathetic acceptance for his ideas only in retrospect, not in prospect.

Summary

From this recital it is apparent that many antiseptics enjoyed wide usage extending back through the Middle Ages to Hippocrates. However, proof of the efficacy of such management was missing until

*Thomas Forster had taken out a patent for a surgical rubber glove in 1878. Sir Thomas Watson (1842) and William Acton (1848) had devised rubber gloves for the protection of the hands of anatomists and surgeons.[104]

†Quoted in Scott, H. H.: *History of Tropical Medicine.* London, Arnold, 1942, vol. 1, p. 29.

Semmelweis established the antiseptic principle of preventing wound infection in the parturient uterus denuded of its epithelium. Collins of the Dublin Rotunda Hospital had achieved equally good results in the prevention of puerperal fever by maintaining high standards of cleanliness in his hospital. He failed to note, however, that the accoucheur's hands were the principal source of conveying the contagion.

A few surgeons who expounded the practice of leaving the wound open in the management of contaminated wounds and in elective surgery (amputation and perineal lithotomy) had achieved low mortality rates not equaled until aseptic surgery came at the turn of the century.

Lister's application of carbolic acid to compound fractures turned the tide against primary amputation for compound fracture, an attitude further strengthened by Reyher's demonstration of the utility of early debridement in gunshot injuries during the Russo-Turkish War of 1876-1877.

Antiseptic management of wounds has disappeared. Of all antiseptic agents, the hypochlorites employed by Semmelweis survived the longest and had a rebirth of interest for surgeons in World War I.*

In my opinion the question of priority for having introduced the antiseptic principle of wound management is not a contest between Lister and Lemaire or Déclat, who preceded Lister in the use of phenol for contaminated wounds. It is more a question of how to divide the laurels properly between Semmelweis, the discoverer who showed the way, and Lister, whose consecutive studies convinced surgeons and the medical profession that antiseptic management of compound fracture obviated primary amputation while minimizing the risk. Crowther (1802) used wound dressings of hot tar with striking success in the management of compound fracture. Larrey (1824) and Bennion (1857) had startling results with benzoin in the management of compound fractures before Lister. The profession took no serious note, however, of these significant contributions.

Our profession hails Semmelweis and Lister and their durable contributions for mankind. The honor can be shared without loss to either. Semmelweis had only a sharp perception to guide him. Pasteur was

*Fifty years ago balsam of Peru enjoyed wide usage in the management of chronic infections and ulcers. It is somewhat strange to learn that its use is being once more considered. In his current monograph on *Fractures* Böhler (1966) recommends its application together with limited debridement for compound fractures.[106] Dr. Jander found that the addition of 1% formalin to balsam of Peru made it an effective antibacterial agent.[107]

Lister's guiding light. Antisepsis was only a preliminary victory in an ongoing battle against wound infection. The adulation of a grateful people, accorded Pasteur and Lister, is well deserved; but who in the history of medicine, guided only by a discerning flash of insight, has made so significant a discovery as Semmelweis? Certainly his name merits placement high on any list of mankind's great benefactors.

Asepsis, the product of a number of disciplines, extended the borders and the safety of surgery considerably. Antibiosis has made additional gains possible. Total conquest of the problem awaits future research and clinical trial.

Conclusion

What significance have this inquiry and recital for us?

In the history of surgery, perhaps no wounds have been so badly managed as those of compound fracture. The disability occasioned by a broken bone and an open wound undoubtedly urged many a surgeon to meddlesome interference. Certain it is that if Crowther's suggestion (1802) or Larrey's (1824) had been tested by any of the distinguished authors of monographs on fracture of the first half of the 19th century, amputation for compound fracture would have ceased to be routine long before the Russo-Turkish War of 1876-1877. That Semmelweis' warning of the threat of infection communicated by unclean fingers had meaning only for wounds of the parturient uterus indicates how slowly the significance of useful information is absorbed, understood and communicated within a discipline. It is definitely the business of authors to know of prior suggestions and progress originating within their discipline. That they fail to interpret and relate advances in other disciplines to their own is understandable and emphasizes the current need for interdisciplinary research and improved communication to which attention has previously been drawn.[108] Certain it is that lessons of the past, besides imparting useful information, can help to light the way for today's inquiring wayfarers.

Acknowledgments

I have had invaluable help from my wife, Sarah D. Wangensteen, research associate in medical history. Mr. Dennis Hammond, research assistant, and Mrs. Jacqueline Smith helped with study of the literature of compound fractures and of puerperal fever. To many librarians at

the University of Minnesota and at the National Library of Medicine I am beholden for patient and competent assistance. Mr. Martin Finch, director of the Department of Medical Art and Photography, University of Minnesota, skillfully arranged the illustrative materials.

With permission of the publishers, several of the photographs are reprinted from references 11, 12, and 40. Figures 5 and 6*a* and *b* are from Erna Lesky.[74] Figure 6*c* is from J. Cruveilhier, vol. 1, book 4, plate 6 (1829-1835). Figures 6*d* and *e* are from A. W. Lea (1910), plates 3 and 4.

REFERENCES

1. Vesalius, A.: *De humani corporis fabrica.* Basel, I. Oporinus, 1543.
2. Harvey, W.: *De motu cordis.* Frankfort, W. Fitzer, 1628.
3. Pasteur, L.: Mémoire sur les corpuscles organisés qui existent dans l'atmosphère. Examen de la doctrine des générations spontanées. *Ann. Sc. Nat. 16*:5-98, 1861. Idem.: Recherches sur la putrefaction. *C. R. Acad. Sc. Paris 56*:1189-94, 1863. Idem.: La théorie des germes et ses applications à la médecine et à la chirurgie. *C. R. Acad. Sc. Paris 86*:1037-43, 1878.
4. Lister, J.: On a new method of treating compound fracture, abscess, etc., with observations on the conditions of suppuration. *Lancet 1*:326, 357, 387, 507; *2*:246, 1867.
   Idem.: On the antiseptic principle in the practice of surgery. *Brit. Med. J. 2*:246, 1867.
5. Koch, R.: Die Ätiologie der Milzbrand-Krankheit, begründet auf die Entwicklungsgeschichte des Bacillus Annthracis. *Cohn's Beitr. Bioligie Pflanzen 2*:277-310, 1876.
   Idem.: *Untersuchungen über die Aetiologie der Wundinfectionskrankheiten.* Leipzig, Vogel, 1878.
6. Garrison, F. H. *An Introduction to the History of Medicine,* 4th ed. Philadelphia, Saunders, 1929, p. 579.
7. Ehrenberg, C.: *Atlas von vier und sechsig Kupfertafeln.* Leipzig, Vos, 1838.
8. Henle, J.: Von den Miasmen und Kontagien und von den miasmatischkontagiösen Krankheiten. In: *Pathologische Untersuchungen.* Berlin, Hirschwald, 1840, pp. 1-82.
9. Lesky, E.: *Ignaz Philipp Semmelweis und die Wiener medizinische Schule.* Verh. XIX, int. Kongr. Geschichte der Medizin Basel, 1964. Basel, Karger, 1966, pp. 347-53.
10. Nicaise, E.: Mondeville et le traitement des plaies au XIVe siècle. *Rev. chir. 14*:64-65, 1894.
11. Wangensteen, O. H. and Wangensteen, S. D.: Military surgeons and surgery, old and new: An instructive chapter in management of contaminated wounds. *Surgery 62*:1105, 1113-115, 1967.
12. Wangensteen, O. H., Wangensteen, S. D. and Wiita, J.: Lithotomy and lithotomists: Progress in wound management from Franco to Lister. *Surgery 66*:949, 1969.
13. Billroth, T.: Beobachtungs-Studien über Wundfieber und accidentelle Wundkrankheiten. *Arch. klin. Chir. 6*:444, 1865.
14. Cooper, A.: *The Anatomy and Surgical Treatment of Abdominal Hernia.* From: 2d London ed., Key, C. A., ed. Philadelphia, Lea & Blanchard, 1844, p. 82.
15. Cooper, A.: *A Series of Lectures on the Most Approved Principles and Practice of Modern Surgery: Principally Derived from the Lectures Delivered by Astley Cooper,* Jones, C. W., ed. 1st Amer. from 2d London ed.

Boston, Ewer, 1823, p. 285.
16. Wangensteen, O. H.: Historical aspects of the management of acute intestinal obstruction. *Surgery 65*:363-83, 1969.
17. McDowell, E.: Three cases of extirpation of diseased ovaria. *Eclect. Repert.* (Philadelphia) *7*:242-44, 1817.
18. Matt. *2*:11.
19. Woodall, J.: *The Surgeons Mate or Military & Domestique Surgery.* London, Bourne, 1655, pp. 46, 52, 159.
20. Purmann, M. G.: *Chirurgia curiosa.* London, Browne et al., 1706, pp. 214-215.
21. Fischer-Defoy, W.: Die Behandlung der Frakturen in Deutschland am Ende des XVII. Jahrhunderts. *Muenchener med. Wochenschrift* (Part 2) *56:* 2018-19, 1909.
22. Lemaire, J.: *Du coaltar saponiné désinfectant énergique, arrêtant les fermentations.* Paris, Germer-Baillière, 1860.
23. Déclat, G.: *Nouvelles applications de l'acide phénique.* Paris, Baillière, 1865.
24. Hippocrates: *The Genuine Works,* Adams, F., transl. London, Sydenham Soc., 1849, vol. 2, p. 60.
25. Malgaigne, J.-F.: *De l'irrigation dans les maladies chirurgicales.* Concours thesis. Paris, Lecaplain, 1842, pp. 5-13.
26. Paré, A.: *Oeuvres complètes.* J.-F. Malgaigne, ed. Paris, Baillière, 1840, vol. 2, pp. 334-335.
27. Garrison, F. H.: *John Shaw Billings: A Memoir.* New York, Putnam, 1915, p. 20.
28. Cahours: Des irrigations continues dans les fractures comminutives des membres. *Bull. gén. thérap. méd. chir. 72*:114-16, 1867.
29. Carter, H. Y.: Case of a compound fracture of the leg; with remarks. *Med. Facts Observ. 2*:1-25, 1792.
30. Carter, H. Y.: An account of the good effects of a solution of sal ammoniac, in vinegar, employed, as a topical application, in cases of lacerated wounds. *Med. Facts Observ. 6*:66-85, 1795.
31. Guyot, J.: Premier mémoire sur l'influence thérapeutique de la chaleur atmosphérique. *Arch. gén. méd. Paris 8:* 273-307, 1835.
32. Laborie, J.: De l'application de l'air chaud, comme moyen thérapeutique, dans le traitement des grandes plaies, d'après le procédé de M. Jules Guyot. *Bull. gén. thérap. méd. chir. Paris 15:* 155-66, 1838.
33. Bérard, A.: Mémoire sur l'emploi de l'eau froide comme antiphlogistique dans le traitement des maladies chirurgicales. *Arch. gén. méd., Paris 7:* 5-34, 317-27, 1835.
34. Godin, A.: Observations d'irrigations continues d'eau froide; recueillies dans le service de M. A. Bérard. *Arch. gén. méd. Paris 1*:343-58, 1837.
35. Macartney, J.: Observations sur la guérison des plaies sans inflammation. *Mem. Acad. roy. méd. Paris 5*:64-67, 1836.
36. Nivet, V.: Mémoire sur l'emploi des irrigations continues d'eau froide dans le traitement des fractures compliquées. *Gaz. méd. Paris 6*:36-43, 49-53, 1838.
37. Erichsen, J. E.: Liston and water-dressing. *Lancet 1*:65, 1879.
38. Crowther, J.: A successful mode of preventing gangrene in compound fractures; as practised by Messrs. William, Robert and John Crowther, in the West Riding of Yorkshire. *Med. Phys. J.* (London) *7*:307-10, 1802.
39. Larrey, D.: Mémoire sur une nouvelle manière de réduire ou de traiter les fractures des membres compliquées de plaies. *J. compl. dict. sc. méd. 20:* 193-200, 1824.
40. Wangensteen, O. H., Smith, J. and Wangensteen, S. D.: Some highlights in the history of amputation reflecting lessons in wound healing. *Bull. Hist. Med. 41*:105, 1967.
41. Larrey, D.: *Clinique de l'Hôpital du Gros-Caillou. Rapport chirurgical sur les dernières journées de juillet 1830.*
42. Adams, W.: *A Sketch of the Principles and Practice of Subcutaneous Surgery.* London, Churchill, 1857, pp. 15-17.
43. Cases of compound fracture in which the wounds were closed with com-

presses soaked in compound tincture of benzoin (under the care of Mr. Bryant). *Lancet 2*:747, 1876.

44. Bryant, T.: Contributions to the subject of compound fracture; being an analysis of 302 cases. *Med.-chir. Trans. 43*:20-28, 1861.
45. Jolieu, J.: *Mémoire sur cent fractures compliquées, guéries.* Paris, Baillière, 1843.
46. Paré, A.: *The Workes of That Famous Chirurgion Ambrose Parey,* Johnson, T., transl. London, Cotes & Young, 1634. Reprint, New York, Milford House, 1968, pp. 582-90.
47. Pott, P.: *Chirurgical Works . . . ed.* [*with*] *a . . . Life of the Author . . . by James Earle.* London, Johnson et al., 1790, pp. 14-16.
48. Biencourt, L.: *Considérations sur le traitement des fractures compliquées de plaie . . .* Thesis. Paris, 1873, p. 14.
49. Reyher, C.: Die antiseptische Wundbehandlung in der Kriegschirurgie. In: *Volkmann's Sammlung Klinischer Vorträge* (Chirurgie, no. 30) pp. 1207-62, 1878.
50. Reyher, C.: Ueber primäres Debridement der Schusswunden. In: International Medical Congress, *Transactions* (London) *2*:587-97, 1881.
51. Puschmann, T.: *Geschichte des Medicinischen Unterrichts von den ältesten Zeiten bis zur Gegenwart.* Leipzig, Veit, 1889, p. 313.
52. Caldwell, T. L.: Case of compound fracture of the thigh, successfully treated. *Med. Examiner 1*:504-06, 1838.
53. Boyer, A.: *The Lectures of . . . upon Diseases of the Bones, Arranged . . . by A. Richerand. . . .* 2 vol. in 1. 1st Amer. ed. Farrell, M., transl. Philadelphia, Humphreys, 1805, pp. 21, 22.
54. Banner, J. M.: A report of the cases of fractures of the larger bones of the extremities . . . *Edinburgh Med. Surg. J. 59*:6-13, 1843.
55. Huguier: [discussion reported] *Bull. Soc. Chir. Paris 16*:302, 1856.
56. de Ségogne, E.-R.: *De l'emploi de de l'alcool dans le pansement des fractures compliquées des plaies.* Thesis. Paris, Parent, 1867, pp. 35-55.
57. Nightingale, F.: *Notes on Hospitals. . . .* London, Parker & Son, 1859, pp. 1-2.
58. Paget, J.: The address in surgery. *Brit. Med. J. 2*:157, 1862.
59. Volkmann, R.: Abstract of a clinical lecture on the treatment of compound fractures. *Med. Times Gaz. 2*:561, 1877..
60. Lea, A. W.: *Puerperal Infection.* London, Oxford Univ. Press, 1910, p. 41.
61. Kehrer, E.: *Anatomie und Physiologie der Schwangerschaft in Biologie und Pathologie des Weibes. Handb. Frauenheilkunde und der Geburtshilfe,* 2d. ed. Berlin, Urban & Schwarzenburg, 1952, vol. 7, pt. 1, pp. 354-55.
62. Kirkland, T.: *A Treatise on Child-bed Fevers . . .* London, Baldwin & Dawson, 1774, pp. 73-74.
63. Pouteau, C.: *Mélanges de chirurgie.* Lyon, Regnault, 1760, p. 182.
64. Simpson, J. Y.: Some notes on the analogy between puerperal fever and surgical fever. *Monthly J. Med. Sc. 11*:414-29, 1850.
65. Simpson, J. Y.: *Obstetric Memoirs and Contributions.* Philadelphia, Lippincott, 1856, vol. 2, pp. 17-25.
66. Semmelweis, I. P.: *Die Aetiologie, der Begriff und die Prophylaxis des Kindbettfiebers.* Reprinted from 1861 ed., with introduction by Alan F. Guttmacher. New York, Johnson Reprint, 1966.
67. Hunter, J.: *Works of . . . , with Notes,* Palmer, J. F. ed. London, Longman et al., 1835, vol. 3, p. 60.
68. Lesky, E.: *Die Wiener medizinische Schule im 19. Jahrhundert. Graz,* Böhlaus, 1965, pp. 215-19, 227.
69. Pasteur, L.: [communication on puerperal fever] *Bull. l'Acad. méd. 8:* 271-74, 1879.
70. Churchill, F., ed.: *Essays on the Puerperal Fever and Other Diseases Peculiar to Women. . . .* London, Sydenham Soc., 1849, pp. 470-72, 479-81, 489.
71. Gordon, A.: *A Treatise on the Epidemic Puerperal Fever of Aberdeen.* London, Robinson, 1795, pp. 63-65, 84-85, 92.
72. Collins, R.: *A Practical Treatise on*

Midwifery, Containing the Result of Sixteen Thousand Six Hundred and Fifty-Four Births. . . . Philadelphia, Haswell et al., 1838, pp. 192-93.

73. Holmes, O. W.: The contagiousness of puerperal fever. *New Eng. Quart. J. Med. Surg. 1*:518, 1843.
74. Lesky, E.: Ignaz Philipp Semmelweis und Wiener medizinische Schule. In: *Osterreichische Akademie der Wissenschaften, Philosophisch-historische Klasse.* Wien, Böhlaus, 1964, vol. 3, pp. 23-89.
75. Sinclair, W. J.: *Semmelweis: His Life and His Doctrine.* Manchester, Univ. Manchester Press, 1909, pp. 27, 80-81, 156, 259.
76. Pringle, J.: *Observations on the Diseases of the Army.* . . . London, Millar, 1753, appendix, pp. 309-403.
77. Pringle, J.: Some experiments on substances resisting putrefaction. *Phil. Trans. Roy. Soc. London 46*:487, 1749-1750.
78. Friedrich, P. L.: Die aseptische Versorgung frischer Wunden. . . . *Arch. klin. Chir. 57*:300-09, 1898.
79. Skoda, J.: Vortrag . . . eine der wichtigsten Entdeckungen im Gebiete der Medicin. *Sitzungsberichte der kaiserlichen Akademie der Wissenschaften. Mathematisch-naturwissenschaftliche Classe* (Part 2), pp. 168-82, 1849.
80. Mayer, L.: Über die pflanzlichen Parasiten der weiblichen Sexual-organe in ihrer praktischen Bedeutung. *Monatsschr. f. Geburtsk. 20*:9-15, 1862.
81. Mayrhoefer, C.: Zur Frage nach der Aetiologie der Puerperalprocesse. *Monatsschr. f. Geburtsk. 25*:124-129, 1865.
82. Späth, J.: Historische Ueberblicke der Vorkommnisse im Wiener Gebärhause seit 1784 bis 1863, mit besonderer Berücksichtigung der Puerperal-Erkrankungen. *Wiener med. Wochenschr. 14*:164-67, 1864.
    Idem.: Mortality in the Vienna Lying-in Hospital. *Brit. Med. J. 1*:476-77, 1864.
83. Sourkes, T. L.: *Nobel Prize Winners in Medicine and Physiology, 1901-1965.* London, Abelard-Schuman, 1966, pp. 315-22, 330-41.
84. Hiller, A.: Ein experimenteller Beitrag zur Lehre von der organisirten Natur der Contagien und von der Fäulniss. *Arch. klin. Chir. 18*:697, 1875.
85. Godlee, R. J.: *Lord Lister.* London, Macmillan, 1917, pp. 53-58, 141.
86. Hebra, F.: Höchst wichtige Erfahrungen über die Ätiologie der in Gebäranstalten epidemischen Puerperalfieber. *Ztschr. der kais. kön. Gesellschaft der Aerzte zu Wien,* (Part 2) *4*:242-44, 1847.
87. Hebra, F.: Fortsetzung der Erfahrungen über die Ätiologie der in Gebäranstalten epidemischen Puerperalfieber. *Ztschr. der kais. kön. Gesellschaft der Aertze zu Wien,* (Part 1) *5*:64-65, 1849.
88. Skoda, J.: Über die von Dr. Semmelweis entdeckte. . . . *Ztschr. der kais. kön. Gesellschaft der Aertze zu Wien 6*:107-17, 1850.
89. Haller, C.: Protokoll der Sektion für Pathologie; Sitzung am, Feb. 23, 1849. *Zeitschr. kais. kön. Gesellschaft der Aerzte zu Wien.* Jg. 5, Bd. 1, p. LV, 1849.
90. Gyory, T.: *Semmelweis' Gesammelte Werke.* . . . Jena, Fischer, 1905, p. 600.
91. Routh, D. H. F.: On the causes of the endemic puerperal fever of Vienna. *Lancet 2*:642-43, 1848; *Amer. J. Med.* Reviews in: *Sc. 17*:509-10, 1849; *Edinburgh Med. Surg. J. 75*:244-51, 1851.
92. Arneth, F. H.: Note sur le moyen proposé et employé par M. Semmelweis [*sic*]. . . . *Ann. d'hygiène pub. méd. légale 45*:281-90, 1851.
93. Arneth, F. H.: Evidence of puerperal fever depending upon the contagious inoculation of morbid matter. *Monthly J. Med. Sc. Edinburgh 12*:505-11, 1851.
94. Murphy, E. W.: Puerperal fever. *Dublin Quart. J. Med. Sc. 24*:1-30, 1857.
95. Wieger, F.: Des moyens prophylactiques mis en usage au grand hôpital de Vienne contre l'apparition de la fièvre puérperale. *Gaz. méd. Strasbourg 9*:97-105, 1849.
96. *De la fièvre puérperale: De sa nature et de son traitement: Communications à l'Académie impériale de médécine.* . . . Paris, Baillière, 1858.

97. Vallery-Radot, R.: *The Life of Pasteur*. . . . New York, Doubleday, Doran, 1928, p. 226.
98. Lister, J.: Note on the double cyanide of mercury and zinc as an antiseptic dressing. *Brit. Med. J. 1*:795, 1907.
99. Berthel, C. F.: *Die antiseptische Behandlung der complicirten Fracturen mit Carbolsäure*. Thesis. Leipzig, 1870, p. 4.
100. Neuber, G.: *Anleitung zur Technik der antiseptischen Wundbehandlung und des Dauerverbandes*. Kiel, Lipsius Tischer, 1883.
101. Bergmann, E.: [visit to Bergmann's clinic] Tenth International Medical Congress, vol. 1, 1891, pp. 318-20.
102. Schimmelbusch, C.: *Die Anleitung zur Aseptischen Wundbehandlung*. Berlin, Hirschwald, 1892.
103. Mikulicz, J.: Das Operieren in sterilisierten Zwirnhandschuhen und mit Mundbinde. *Zentralbl. Chir. 24*:713, 1897.
104. Randers-Pehrson, J.: *The Surgeon's Glove*. Springfield, Ill., Thomas, 1960, p. 15.
105. Halsted, W. S.: Ligature and suture material . . . also an account of the introduction of gloves. . . . *J.A.M.A. 60*: 1123-24, 1913.
106. Böhler, L. *The Treatment of Fractures*. New York, Grune, Stratton, 1966, p. 2310.
107. Jander: Experimentelle Untersuchungen über bakterienfeindliche Eigenschaften des Perubalsams. *Arch. klin. Chir. 90*: 529-42, 1909.
108. Wangensteen, O. H.: Role of medical history as incentive to scholarship and spur to interdisciplinary research. *Mayo Clinic Proc. 42*:345-49, 1967.